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# Impact of Microwave Treatment on the Functionality of Cereals and Legumes

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## ABSTRACT

Microwaves are known to induce compositional, nutritional and functional changes in majority of the food systems. The objective of the present studies was to investigate the effect of microwave heating on protein solutibility and on the functional properties of a cereal, legume and their blends as such information will facilitate the processing and new product developments consisting of the above ingredients. The three samples i.e. a cereals (wheat flour & *haleem flour*) legumes (red bean flour) were used to evaluate the effects of microwave heating on their functional properties such as the water holding, oil binding, emulsifying, foaming capacities and the protein solubility index. It was found that all the microwave treated (MWT) samples produced significantly enhanced values of the above mentioned characteristics as compared to the microwave untreated (MWU) counter parts. The time for MWT as 50 s, 90 s and 300 s was found to alter the functionality of the three selected flours. Protein solubility in general was increased during MWT for a short period of time and decreased with increase in the time of treatment. The results have indicated that MWT of the raw materials for a limited time period will be helpful in designing the processing system and determining the quality of processed foods. © 2011 Friends Science Publishers

**Key Words:** Water holding capacity; Oil binding capacity; Emulsion capacity; Microwave treatment (MWT); Red bean; wheat; *Haleem* wheat

## INTRODUCTION

Legumes, the seeds of the pod-bearing plants belonging to the order *Leguminosae* are the major source of diet consisting complex carbohydrates, dietary fibers, proteins, vitamins, minerals and variety of phytochemicals. In Africa, per capita consumption of proteins and essential amino acids is generally very low and legumes represent the major source of proteins in the diet (Araujo *et al*., 2002). Although the production of legumes is relatively less as compared to cereals however, they play key role in protein enrichment all over the world (FAO, 1980). In spite of the high nutritive values, some of the legumes are still underutilized; on the other hand protein deficiency in diet is widespread in many of the underdeveloped countries (Adebowale & Lawal, 2004).

The interest for utilization of legumes are constantly increasing in industry, in view of their functional properties such as the water absorption, emulsifying, swelling, pasting and foaming capacities etc., which play the significant role in new product developments. The legume enriched processed foods have already been produced such as the sausages, soups, confectionery, salad dressing, frozen desserts and the bakery products (Ahmedna *et al.,* 1999). The red bean consisting approximately 30.2% proteins is rich in nearly all the essential amino acids and fulfill the requirement of WHO and FAO for protein fortification (Chau *et al*., 1998). The beans and insoluble dietary fibers were also used in the past for therapeutic purposes such as ameliorating symptoms of dropsy, diarrhea and for curing the viscera (Li *et al.,* 1973; Sarikhan *et al*, 2009).

Wheat (*Triticum satvium*), a major cereal crop is used commonly as the diet source for half of the world population and contribute more than 60% to the total proteins requirement in developing countries. Wheat proteins have lysine as the main limiting amino acid, following tryptophan, thereonine and methionine. The consumption of gliadins, a kind of prolamins causes celiac disease in gluten intolerant individuals (Thompson, 2001). However, the importance of wheat proteins is attributed to their unique viscoelastic properties where gas is occluded and retained in the liquid phase during dough development from the flour, water and other ingredients. The gluten-starch matrix form the cell membranes that surrounds the expanding gas cells during fermentation and mixing (Lagrain *et al.,* 2005; Baninder *et al.,* 2009). The mixing process facilitates the different flour proteins interactions within themselves and with the starch, which manipulates the gelatinization temperatures, rate of water evaporation and reterogradation etc. The intermoleculars movements and the formation of their

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complexes govern the end quality of the baked products (Mohamed *et al.,* 2003; Ying *et al.,* 2006).

Microwave baking is a rapid method as compared to the convectional heating and the effect of the MW heating on the grains to limit the moisture without changing the other properties has been investigated for facilitating the product development (Macarthur & Dappolonia, 1982; Campana *et al.,* 1986). It has been reported that the physical and chemical properties such as the viscosity, elasticity, hydrophobicity, damage starch, total starch, water absorption capacity etc., were not significantly changed during MW heating as revealed by the graphic characteristics (Kaasova *et al.,* 2003) however, the initial moisture and the extent of input of the MW energy are critical parameters in maintaining the native properties of the ingredients. The baking quality was further improved by using the sprouted wheat and it was found that falling number and gluten index increased by increasing the MW energy, in view of the fact that amylase gets inactivated and the number of the disulphide bridges increased however, the wet gluten content decreases as a consequence of higher energy consumption (Kaasova *et al.,* 2002). The MW treatment has illustrated that grassy, beany and gumy flavor of pulses may be desirably reduced in various type of the processed foods (Yun *et al.,* 2005). The MW drying as compared to the conventional method enhanced the quality of lentils (Opoku *et al.,* 2009). The spread ratio (width/height) values were suggested for rapid evaluation of the end quality of baked products (Dogan *et al.,* 2002). Recently, Arab *et al.* (2010) have reported the cooking quality of the spaghetti by using MW oven and Dogan *et al.* (2010) developed a combination of spread ratio and microwave baking test to evaluate the flour properties for bread processing. Very recently, Tochampa *et al.* (2011) have found that MW heating has no adverse effects on chemical, microbiological and sensory properties of sweet fermented glutinous rice, a tradition desert in Thai called Khao-Mark.

The rationale behind the present study is to understand the changes in functional properties such as the protein solubility, foaming, emulsifying, water holding and oil binding capacities of the wheat, red bean and *haleem wheat* flours, which were found to facilitate the food processing.

## MATERIALS AND METHODS

**Materials:** Vegetable oil (Eva brand), Red bean , wheat and *haleem wheat* grains were purchased from the local Makro Super Market, Karachi and manual screening was used to remove foreign materials from the seeds. Flours were prepared by using household mill (Braun multimix deluxe Germany) to obtained 80 mesh size of the flour, and stored in refrigerator at about 4°C. All chemicals and reagents used were of analytical grade.

**Microwave treatment:** MW oven whirlpool l243/ukm347 (Norrkopping, Sweden) with frequency 2450 MHz and inner volume 25.41 L, was preheated to achieve a standard uniform temperature, by first heating 200 mL of water for 50 s. The samples (100 g each) were heated in a polyethylene container for 50 s, 90 s and 300 s and were left for 1 min. in the oven for cooling. The samples were manually mixed with the spoon to achieve the homogeneous heating.

**Determination of Functional Properties of Red Bean, Wheat and *Haleem Wheat* Flours**

**Water holding capacities (WHCs):** WHCs of each of the samples was determined using the method of Beuchat (1977), briefly describing 1 g of flour was taken in 10 mL of distilled water and mixed vigorously for 2 min, and cooled to 25°C. The supernatants obtained after centrifugation at 3000 g for 20 min, were decanted and the weights of the sediments were observed, the WHCs values expressed as gram of water absorbed by 100 g of flour.

**Oil binding capacities (OBCs):** The OBCs were determined of the red bean flour, wheat flour and *haleem wheat* flour by using the method of Chakraborty (1986). Briefly describing 1 g (W°) of flour was taken into the pre-weighed 50 mL centrifuge tubes and thoroughly mixed for 3 min with 10 mL ($V_1$) of vegetable oil using a vortex mixer. Samples were allowed to stand for 30 min and the mixtures were centrifuged at 3000 g for 20 min, the supernatants were carefully poured separately into the 10 mL graduated cylinders, immediately after the centrifugation. The volumes were recorded ($V_2$) and oil absorption capacity (milliliter of oil per gram of flour) was calculated as:

$$OBC = (V_1 - V_2)/W°$$

The samples were analyzed in triplicate for each flour.

**Emulsifying capacity (EC):** ECs and ESs (emulsion stabilities) were determined in triplicate according to the method described by Sath and Salunkhe (1981) with slight modifications. The samples (2 g) of each of the flours were mixed with 40, 50, 60, 70 and 100 mL of distilled water for 2 min. using an Osterizer blender and 200 mL of vegetable oil was added slowly with continuous blending. The process was stopped after every 2 min to check for emulsion breakage. EC of the samples was determined by using a model system as described by Zorba *et al.* (1993). The final end point was determined by Ohm meter measuring the electrical conductivity as described by Webb *et al.* (1970).

**Foaming capacity (FC) and foaming stability (FS):** FCs and FSs of red bean, wheat and *haleem wheat* flours were determined in triplicate using the method described by Makri *et al.* (2005). Briefly describing 1% flour in de-ionized water was taken, pH was adjusted to 7.4 with 0.1N NaOH and 0.1N HCl. The MWT and MWU samples of red bean flour, wheat flour and *haleem wheat* flours (Vi, 100 mL) were blended for 3 min and poured into a 250 mL graduated cylinder. The volume of foam ($V_f$) was immediately recorded and FC was calculated using the following equation:

$$FC = Vf - Vi$$

**Protein solubility (PS):** The MWT and MWU samples of the flours from red bean, wheat and *haleem wheat* flours were mixed with water separately in a ratio of 1/20 (w/v), the pH of each of the mixtures was adjusted separately from pH 2.0–10.0 in different test tubes using 0.1 N NaOH and 0.1 N HCl. The red bean, wheat and *haleem wheat flour* suspensions were stirred at room temperature for 1 h, and then centrifuged at 3000 g for 15 min. using Eppendorf centrifuge 5810 r. The soluble protein concentration in each supernatant was determined at 595 nm (Bradford, 1976).

## RESULTS AND DISCUSSION

The chemical composition of pulses including beans has proved that protein, fat, ash, dietary fibers are higher than reported in wheat, which has stimulated food industries to incorporate legumes in the bakery products for nutritional supplementation. However, it is essential that functional properties of the various components of legumes and cereals should complement each other for the processes concerned. During the last few decades cereal cum legume based products are significantly increased in number in view of enhanced nutritional benefits. We therefore investigated the functional properties of the red bean, wheat and *haleem wheat* flours and specially the effect of microwave heating on each flour, because MWT has been reported to alter the cooking quality, spread ratio, sensory and color attributes of baked products.

Food processing methodology has important impacts on the protein conformation, folding and unfolding of polypeptide chains that change the behavior of proteins in a system. MWT has significantly changed the functional properties of red bean, wheat, *haleem wheat* flours suitable for processing as described in the following sections.

**Water holding capacity:** The data presented in Table I has shown, that WHC of the native red bean and *haleem wheat* flours are less than native wheat flour, while MWT has increased the WHC of all the three types of the flours. The MWT during all the intervals of time show that WHC increases as: red bean flour > wheat flour > *haleem wheat* flour. The increase in WHC of red bean flour was recorded as the highest as it raised from 4.419 to 6.123 mL per 100 g of flour. MWT at 300 s has the highest WHC, which may be due to uncoiling and more exposure of the hydrophillic domains of the various proteins, responsible for increase in water absorption. The WHC in dough play critical role in postulating the texture of the end product as during heating, protein gets denatured (uncoiled) and release water absorbed by them, which immediately is taken up by starches and fiber (pentosans) of both the cereals and legumes. The extent of

**Table I: Effect different Microwave treatment on physicochemical properties of red bean flour, wheat flour and *haleem wheat* flour**

| Variety | Microwave Treatment (s) | Water Holding Capacity (ml) | Oil Binding Capacity (ml) | Foaming Capacity (ml) | Foaming Stability (min) | Protein Solubility pH 7 |
|---|---|---|---|---|---|---|
| | 0 | 4.419±0.25[a] | 4.553±0.14[b] | 4.419±0.24[c] | 9 | 1.61±0.11[d] |
| Red bean flour | 50 | 4.738±0.31[a] | 4.964±0.21[b] | 4.738±0.31[c] | 20 | 1.64±0.09[d] |
| | 90 | 5.308±0.16[a] | 4.861±0.25[b] | 5.308±0.13[c] | 10 | 0.92±0.03[d] |
| | 300 | 6.123±0.39[a] | 3.897±0.33[b] | 6.123±0.19[c] | 15 | 0.65±0.08[d] |
| | 0 | 5.142±0.38[a] | 4.765±0.30[b] | 5.142±0.21[c] | 8 | 1.32±0.07[d] |
| Wheat flour | 50 | 4.407±0.15[a] | 5.4±0.09[b] | 4.407±0.15[c] | 15 | 1.33±0.06[d] |
| | 90 | 3.969±0.10[a] | 5.184±0.28[b] | 3.969±0.18[c] | 10 | 1.03±0.08[d] |
| | 300 | 5.381±0.20[a] | 3.879±0.27[b] | 5.381±0.34[c] | 14 | 1.14±0.13[d] |
| | 0 | 4.452±0.16[a] | 4.485±0.17[b] | 4.452±0.24[c] | 6 | 1.29±0.09[d] |
| Haleem wheat flour | 50 | 4.426±0.27[a] | 4.568±0.21[b] | 4.426±0.13[c] | 14 | 1.28±0.05[d] |
| | 90 | 4.591±0.10[a] | 4.465±0.31[b] | 4.591±0.24[c] | 11 | 0.97±0.12[d] |
| | 300 | 4.918±0.27[a] | 4.781±0.20[b] | 4.918±0.32[c] | 12 | 1.20±0.14[d] |

Value is ±SEM (standard error of mean), n=3

Variety of the flour samples values compared to each other, same small letter within a column had no significant difference calculated by LSD method.

**Table II: Emulsion capacities of different microwave treated sample**

| | | Water and Oil ratio (ml) in formation of stable emulsion | | | | |
|---|---|---|---|---|---|---|
| **Variety** | **Microwave Treatment (s)** | **Water 40 mL** | **Water 50 mL** | **Water 60 mL** | **Water 70 mL** | **Water 100 mL** |
| | 0 | 20 | 39 | 35 | 40 | 60 |
| Red bean flour | 50 | 37 | 50 | 56 | 63 | 72 |
| | 90 | 20 | 39 | 30 | 49 | 48 |
| | 0 | 41 | 40 | 31 | 29 | 74 |
| Wheat flour | 50 | 18 | 30 | 50 | 22 | 33 |
| | 90 | 8 | 16 | 13 | 18 | 17 |
| | 300 | 11 | 17 | 22 | 10 | 10 |
| | 0 | 24 | 22 | 40 | 38 | 76 |
| Haleem wheat flour | 50 | 15 | 19 | 28 | 45 | 40 |
| | 90 | 9 | 13 | 8 | 13 | 15 |
| | 300 | 9 | 19 | 18 | 10 | 12 |

**Fig. 1: Comparison of WHC of WF, HWF, RBF**

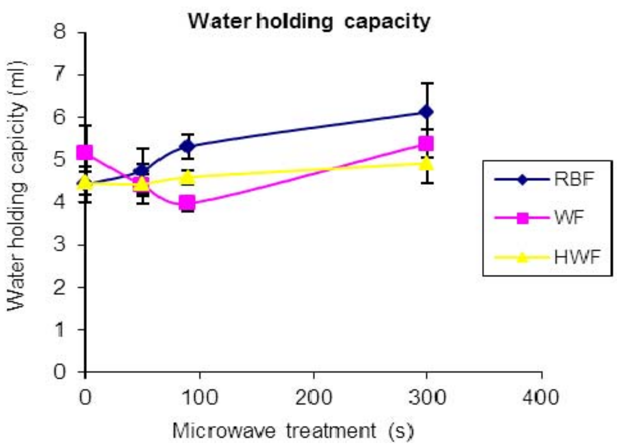
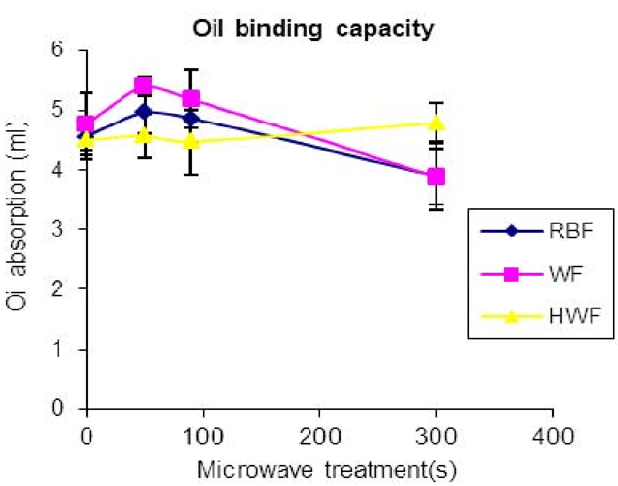



**Fig. 2: Comparison of OBC of WF, HWF, RBF**




gelatinization of starches is dependent on the availability of water and determines the final texture and size of the baked products. So the quality and quantity of various types of proteins, starches and dietary fibers in any raw material will predict the texture at the end of baking. MWT of cereals and legumes is able to increase the WHC, which often is required in baked products to make the texture harder and crispy. Statistical results show insignificant difference in the values. Fig. 1 is indicating that there is no linear relationship between WHC and MWT in all flour samples.

**Oil binding capacity:** The OBC as shown in Table I are similar (4.485 to 4.765) in the untreated flours and increased during MWT up to 5.184 in case of wheat flour however, the capacity of oil binding behaves differently with increase of time of the MW treatments. MW heating for 50 s has increased OBC in all the three samples, while it decreased with further heating as indicated in Fig. 2. This behavior may be attributed to the extent of the insolubility of proteins. The wheat proteins (gluten) are almost insoluble in water and have shown maximum 0.7 mL capacity of oil absorption in wheat flour after 90 s, while red bean flour

**Fig. 3: Comparison of FC of WF, HWF, RBF**

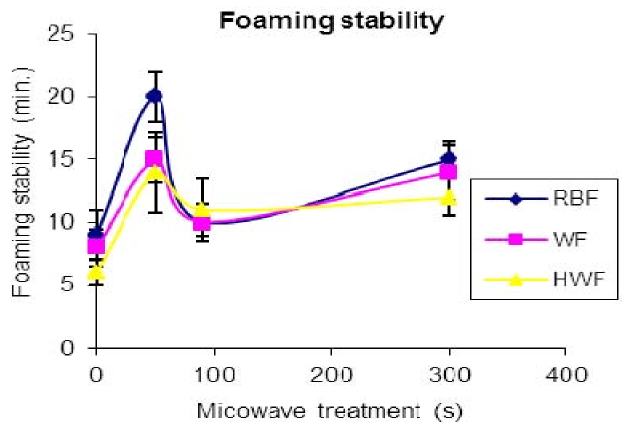



**Fig. 4: Comparison of FS of WF, HWF, RBF**

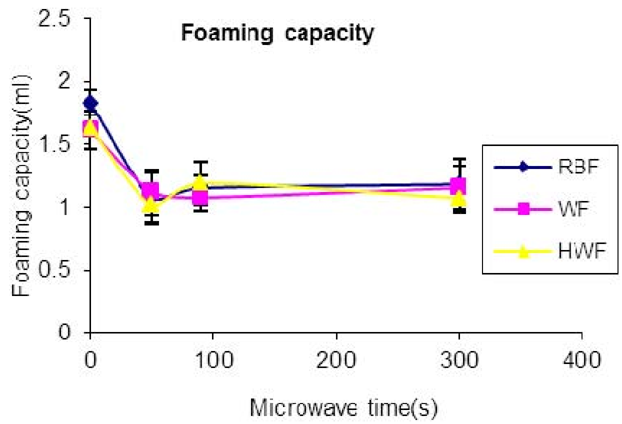
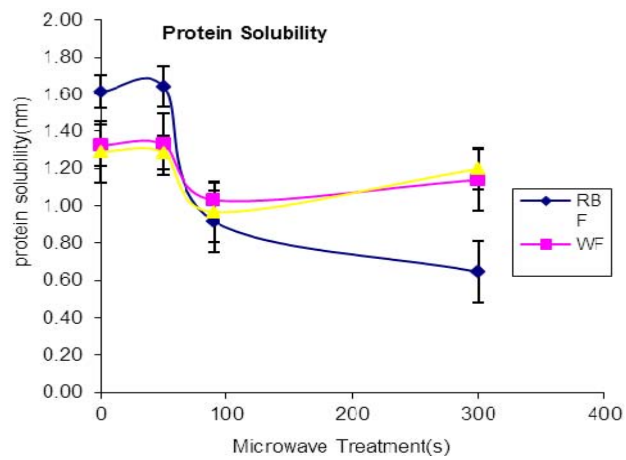



**Fig. 5: Comparison of PSI of WF, HWF, RBF**




proteins have more proteins (23-30%) as compared to wheat where total protein contents range 7-9%. In spite having larger quantity of proteins, red bean flour absorbed only 0.4 mL of fat because of lesser amount of hydrophobic amino acids responsible for insolubility of proteins in water and higher solubility in oil.

The OBCs of the all native flours is increased as

MWT intervals also increased, and fat absorption is important in achieving the desired texture of the end products. During MWT proteins were denatured when heated for 50 s, 90 s or 300 s exposing hydrophobic sites that increased lipid interaction leading to elevated OBC. Statistically there is no significant difference (P>0.05) in the behavior of different varieties of flours.

**Foaming capacity and stability:** The formation of foams where water molecules surround air droplets represents the non-polar phase and is related to soft texture of food products. Some proteins and peptides in dispersion are capable of reducing the surface tension at the water-air-interface that leads to foaming. The proteins and their hydrolysates are good foaming agents as they easily diffuse into the air-water interface forming cohesive, adhesive and elastic films by partial unfolding themselves. The foaming capacity of proteins is strongly related to number and matrix of the hydrophobic amino acids which are exposed at the surface of the protein molecules (Kong *et al*., 2007). The maximum foaming capacity was achieved at 300 s in MWT in all the flour samples as shown in Table I. Therefore, MWT flours may be suitable in food system that requires foaming, such as the cake, bread and ice-cream. As expected an increase in foaming capacity was observed with the increase in the protein concentration that further confirmed the earlier reports (Sath & Salunkhe, 1981; Akintayo *et al*., 1999). Red bean flour has the high FC as compared to the wheat flour and *haleem wheat* flour at treatment for 300 s its means that greater exposure of hydrophobic amino acids as shown in Fig. 3. It also proves that MWT stimulate protein unfolding and protein–protein interactions, which elevates the viscosity and facilitates the formation of multilayer cohesive protein film at the interface of bubbles, offering resistance to coalescence. Thicker films limit the drainage of proteins from films and provide stability to air bubbles. The dialysis of the hydrolysates has further supported the findings as permeate of the MW membrane dialysate show the lowest foam stability. Stable protein foams are best obtained due to the inclusion of some large solvated peptides left after the limited proteolysis of the gluten (Surowka & Fik, 1992). Maximum foaming stability of all samples was achieved at 50 s of MWT (Fig. 4).

**Protein solubility (PS):** Solubility is expressed as the soluble protein which determined by Bradford assay. Increase in solubility is not only due to the size reduction of the protein molecules but it involves also the reduction of the secondary structure of the parent protein molecules. PS is the mutli-functional property as it influences many other properties and collectively governs the behavior of proteins in the food system. MWT induces both desirable and undesirable effects on the flour samples of red bean, wheat and *haleem wheat* flours. It inactivates the anti-nutrients such as the trypsin and amylase inhibitors in legumes, thus improving the bioavailability and digestibility of the proteins and starches (Snyder & Kwon, 1987). MWT adds pleasant flavor and aroma to all the flour samples especially red bean flour. MWT significantly affects the functionality of all flours due to variety of changes in the macronutrients including the protein components such as agglomeration, denaturation and protein aggregations interactions with other ingredients as shown in the Table I. Decrease in the PS value after MWT can be explained by the effect of heating, which increased surface hydrophobicity of protein due to unfolding of the helical secondary structure, exposure of the hydrophobic amino acids their interactions and formation of the disulfide bonds. The maximum protein solubility concentration of all varieties was found in the untreated form at pH 7 showing that the yield rated polypeptide units were produced as a consequence of MWT that did not support aggregate formation even at its isoelectric pH (Kong *et al*., 2007). Electrostatic interactions, which involve ionization of the interior non-polar groups by addition of alkali or the acid, lead to disruption of the native structure of the proteins, thus shifting the equilibrium. The pattern of protein solubility is shown in Fig. 5.

**Emulsifying capacity (EC):** The EC is ability of proteins to diffuse at the oil-water interface and to develop inter-linkages with water and hydrophilic amino acids and oil with hydrophobic amino acids simultaneously. So protein molecule is acting as a hanger for oil and water droplets. The MWT widened α-helical structure of proteins to act as the efficient hanger. Food emulsions are thermodynamically unstable mixtures of immiscible liquids (water & oil). The formation and stability of emulsions is required during the processing to modify the food systems to become desirable. The role of proteins as emulsifiers in food processing is well recognized as a result of the binding of water and oil with proteins simultaneously. Formations of such complexes help in food systems because of their effects on the flavor and texture of the final products. The hydrophilic and hydrophobic properties facilitate both water and oil to be mixed in food systems (Agyare *et al.,* 2009). The MWT of red bean, *haleem wheat* and wheat flours for 50 s in various flours improved EC due to an increase in balanced surface availability of hydrophobic and hydrophilic amino acids. The data in Table II indicates that MWU consume maximum amount of oil to make emulsion, while in MWT need only small quantity of oil for excellent emulsion formation with strong stability. The EC at 50 s has shown that red bean flour > wheat flour > *haleem wheat* flour, which may be attributed to increased protein content of red bean flour. More globulin proteins get solubilized in salt solutions thus increasing the exposure of more hydrophobic groups at the water and oil interface, resulting in increased EC and stability of the emulsion. Moreover, the neutral pH has minimal EC, while either acidic or alkali pH facilitate emulsion formation showing the isoelectric points of the proteins are important in formation of emulsions (Wang *et al*., 2006).

## CONCLUSION

Some functional characteristics of the red bean, wheat and *haleem wheat* flours may be improved by MWT. The MWT is responsible for numerous changes in the structures of macro and micro molecules including gelatinization, viscosity, hydrophobicity etc. Water absorption properties of red bean, wheat and *haleem wheat* flours were enhanced at increased MWT. MWT of the flours showed better OBC, FC and EC than the normal flours and are suitable for product development. Proteins with high oil and water binding are desirable for use in meats, sausages, breads and cakes, while proteins with high emulsifying capacity are good for sausages, bologna, soups and salad dressing. The high EC after MWT of flours proves that the process may be helpful in production of variety of foods such as salad dressing, creamy soups and ice creams etc.

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